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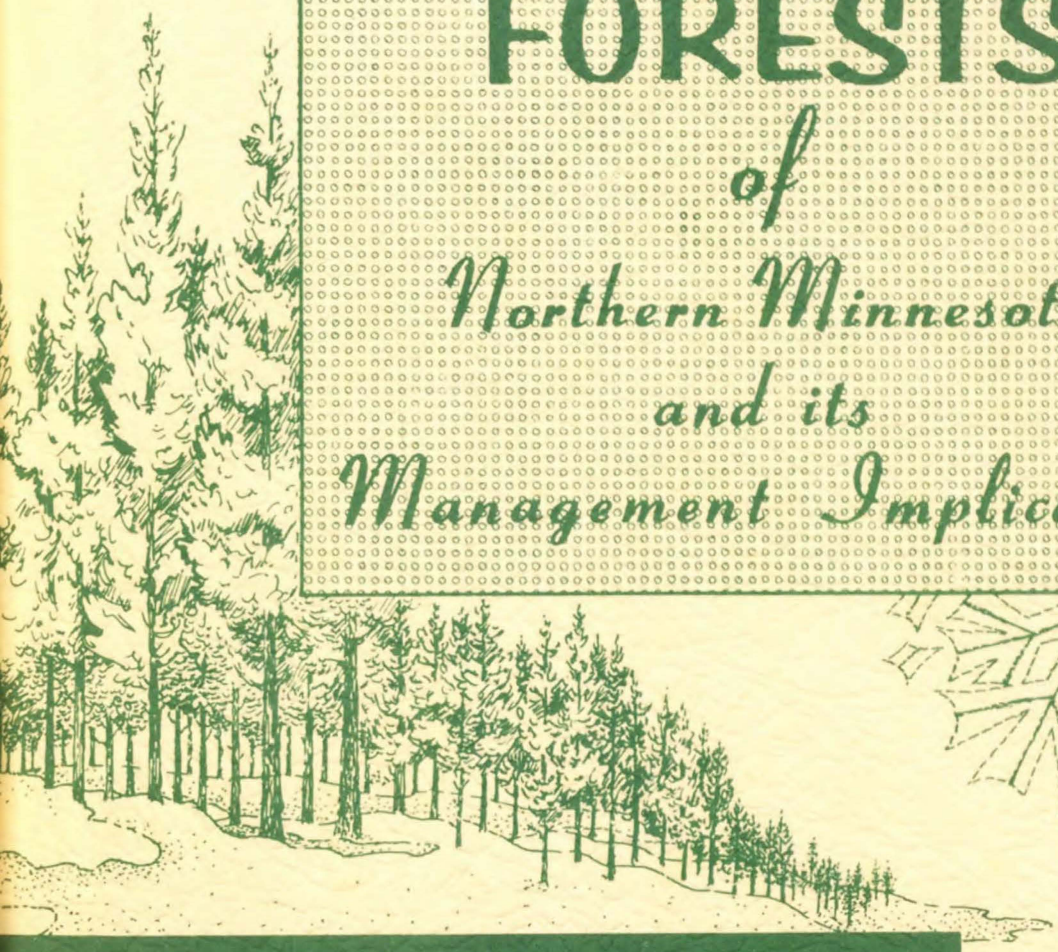
SNOW BEHAVIOR in FORESTS of Northern Minnesota and its Management Implications



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Snow Behavior

in forests of northern Minnesota and its management implications

By Sidney Weitzman and Roger R. Bay[1/]

How forest cover affects water behavior is now being studied as part of an overall program of watershed management research in the Lake States area. This report covers some first results of one phase of the study--snow accumulation and melt in the forests of northern Minnesota during the winter of 1956-57.

Problem

Very little information on snow behavior is available for northern Minnesota conditions, even though 20 percent of the total precipitation comes in the form of snow (2, 3). This amounts to approximately 5 inches of water each year (14). Thus, the behavior of snow under different forest cover conditions may have important effects on the water resources of the area.

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Between 1870 and 1920 most of the area was logged commercially and burned. Aspen and brush species rapidly invaded the former conifer lands; today, $4\frac{1}{2}$ million acres of former pine lands are occupied by other species, mostly aspen. Since 1920 more than 360,000 acres have been planted and the effort is increasing annually (5). This study should help to determine the effect of these wholesale conversions on the amount of snow caught and its rate of melt. Did the change from pine forests to aspen modify the timing of melt so millions of acres release their water simultaneously in the spring? What changes need to be made in present cover so that water can be retained longer on the ground and thus provide opportunity for gradual melt and infiltration?

In addition, the effect of current management practices in existing types was studied. Cutting methods and thinning practices are usually guided by anticipated silvicultural responses. Since forest cover has many functions, it seems wise to determine the role of treatment and cutting on water behavior as well as timber production. What cutting systems allow more snow to accumulate or delay its melt longest in the spring?

The results of this study on snow accumulation and melt will thus help fill a gap in our knowledge locally. This, in turn, will help supply knowledge needed to do a more effective job of flood reduction (13) (figs. 1 and 2). The data should also indicate how forest practices and watershed management are interrelated.

Figure 1.--As much as 50 percent of total annual runoff may occur in a 2-month period in early spring when snowmelt occurs.

Figure 2.--
Flooding is a
common spring
event.

Areas and Types Studied

Snow was studied on three major forest types in northern Minnesota: red pine, aspen, and black spruce.

1. The red pine stands observed were thinned to 60, 100, and 140 square feet of basal area. Also studied was an adjacent aspen pole stand and an open grassy area.

2. The aspen stands studied were thinned to 50, 65, 80, and 115 square feet of basal area. These were compared to each other and to a young brushy hardwood stand, two young pine stands, a mixed pine-hardwood stand, and an open grassy area.

3. Five cutting methods in black spruce were observed. These were a clear-cut strip oriented east-west, a shelterwood cut, individual tree selection, an uncut stand, and an open clear-cut patch.

Thus, data on snow accumulation and melt were compared in two ways: (1) Under different densities or cutting methods within each forest type, and (2) between the several forest types and on brush or open land.

Methods

Snow-depth and water-equivalent measurements were taken prior to the peak accumulation and carried on to trace the period of snow disappearance. Measurements were begun in January in the red pine and aspen areas and in February in the black spruce area; thereafter they were taken at intervals of about 3 weeks throughout the winter and at closer intervals during the spring melt. The last ones were made in April, at which time there was still some snow under most cover conditions, even though it had already disappeared from several cover types.

On each sampling date, 10 samples were taken in each condition.[2/]

Comparison of Thinned Red Pine and Aspen

Results

The trend of snow accumulation and melt under the three different stocking levels of red pine, a nearby aspen stand, and an open area is shown in figure 3. The depth of snow that accumulated and the order of melt were as expected.

During the period of accumulation, which began with the first snowfall in December and lasted until early March, the effect of crown interception was quite noticeable. Of the forested areas studied, the fastest and deepest accumulations were under the aspen stand, which provided a poor barrier to snowfall, and under the red pine stand thinned to the lowest basal area (60 square feet). These were followed by the red pine stand with 100 and 140 square feet basal area.

During the melt period, from early March to mid-April, the shading effect of the forest became evident. Snow disappeared first from the open area which was exposed to the direct rays of the sun, next from the leafless aspen area, and last from the densest red pine stand.

The amount of snow left on the ground at any one time during spring melt is the result of two factors--the depth and density of snow when melt started and the rate of melt. Snow depth and density at the

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2/ A Mt. Rose snow tube and tubular scales were used.

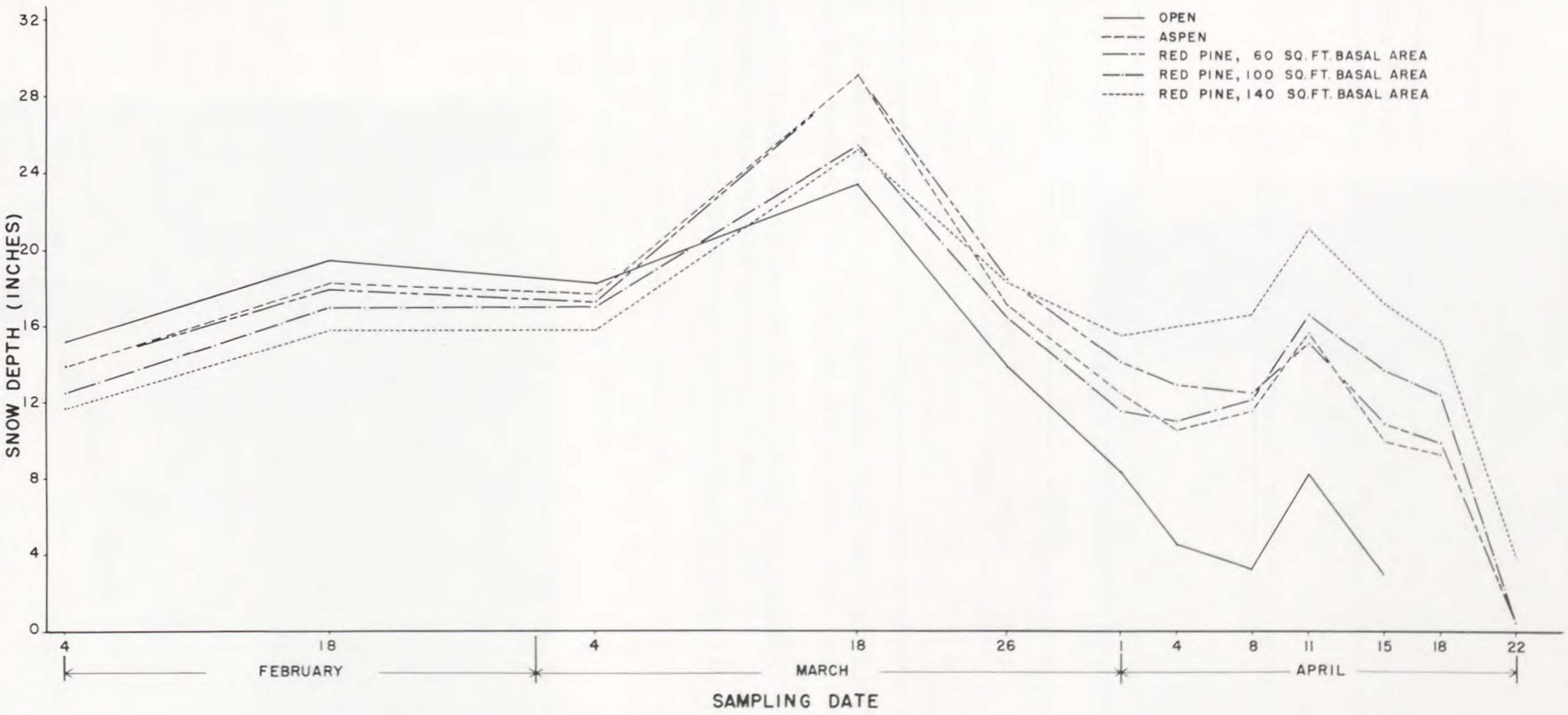

Figure 3.--Snow accumulation and melt by forest cover types.

start of melt were different for each stocking level and cover type. The subsequent rates of melt under each were also different.

The water content of the snowpack followed the same general trend of snow depths but the differences were smaller. Table 1 shows the water retained in the snowpack toward the end of the melt period. Figures 4 and 5 illustrate relative snow conditions.

Table 1.--Water contents during melt period

(Inches)

Date	Cover type				
	Open	Natural aspen	Red pine 60 sq. ft.	Red pine 100 sq. ft.	Red pine 140 sq. ft.
April 11	1.60	3.30	3.10	3.80	4.70
April 22[1/]	0	0	.13	.14	[2/]1.10

1/ This was the last sampling date. Exceptionally high temperatures combined with warm rains melted all the snow before the next sampling date.

2/ Water-content differences between the heavily stocked red pine (140 sq. ft. b.a.) and each of the other cover conditions were found to be statistically significant at the 95-percent level of significance.

Figure 4.--Snow in aspen stand starting to melt.

Figure 5.--Red pine stand with complete covering of snow.

Management Significance

Thinning is an accepted timber management practice in dense red pine stands. The results of this study indicate that the practice will allow slightly more moisture to accumulate without causing accelerated spring melt and runoff. The densest stand held back a little more moisture than the lighter stocked stands at the time of the last spring measurement.

The conversion of aspen stands to conifers is often recommended in the interest of improving forest quality and increased dollar return. This study indicates that growing a larger proportion of conifer stands in the area may also provide watershed benefits. Snow disappeared earlier and more rapidly under aspen than under the pine stands. A greater proportion of pine stands would thus help delay the simultaneous release of snow water from a large area.

Comparison of Thinned Aspen, Conifers, and Brush

Results

The study of snow behavior under different stocking levels in aspen indicates that the densest aspen stand had a deeper snowpack toward the end of the melt period (table 2). The differences, however, are not large. This is not surprising since hardwoods in winter are a poor barrier to the sun's melting rays (12).

Table 2.--Water content under aspen stands of different stocking levels

(Inches)

Date	Basal area			
	50 sq. ft.	65 sq. ft.	80 sq. ft.	115 sq. ft.
January 9	1.4	1.3	1.3	1.3
February 5	2.2	2.3	2.2	2.1
February 19	3.0	2.9	3.0	2.3
March 4	3.2	2.9	3.0	3.1
March 22	4.5	4.1	4.2	4.3
March 28	4.3	4.0	4.0	3.9
April 4	3.5	3.2	2.7	3.2
April 11	3.2	2.5	3.5	3.9
April 17[1/]	2.6	2.2	3.1	3.4

1/ This was last sampling date in which snow was on ground.

Table 3 shows the snow depth and water content at the time of the last measurement for areas of aspen (all densities combined), conifers, mixed pine-hardwood, and brush and hardwood as well as for an open area. Data for a red pine and a jack pine area were combined under "conifers," as differences in water content were minor.

Table 3.--Snow depth and water content under various cover types on April 17, 1957

(Inches)

Cover type	Snow depth	Water content
Open	0.0	0.0
Brush and hardwood	6.6	2.0
Aspen	8.1	2.8
Conifers	11.4	3.4
Mixed pine-hardwood	13.4	3.9

The mixed white pine-hardwood stand collected and retained more snow water than any other forest type. The holes in the canopy, formed by the scattered hardwoods, and the flexible white pine needles allowed a large amount of snow to reach the ground. At the same time the white pine provided protection against direct insolation and thus retained more snow longer.

The difference in water content of aspen versus conifers at the time of the last measurement was again apparent in this area.

The brush and hardwood sapling stand was intermediate in its behavior between open and aspen areas. It collected more snow than the aspen stands but lost it faster.

The pictures in figures 6 and 7, also taken on the date of the last measurement, illustrate differences in depth between aspen and mixed pine-hardwoods.

Figure 6.--Sampling aspen stand on April 17, 1957. Snow depth was 8.1 inches, moisture content, 2.8 inches.

Figure 7.--Sampling white pine-hardwood stand on April 17, 1957. Snow depth was 13.4 inches, moisture content, 3.9 inches.

Management Implications

The softwood types in our present forests account for only 30 percent of the forest areas. This is in marked contrast to the original forests of northern Minnesota which were almost entirely coniferous. Millions of acres, however, contained scattered hardwoods mixed in with the conifers. The white pine-hardwood stand studied is representative of that condition. This condition must be rated first in its ability to retain snow the longest and to catch the greatest accumulation on the ground.

It would thus appear that forest management practices that encourage conversion of pure aspen to mixed conifer-hardwood stands are desirable. Logging practices and release cuttings that increase the percentage of conifers in aspen and hardwood stands would also improve conditions for snow accumulation and melt. Scattered block plantings and belts of conifers within aspen and hardwood stands also appear desirable.

Reforesting open areas or nonproductive hardwood and brush areas with conifers will result in more favorable spring snowmelt characteristics. These areas will thus provide both timber and watershed benefits.

Aspen stands were more effective in retarding snowmelt than either open or brushy areas. Thinning of pure aspen stands for increased growth had a limited effect on moisture retained in snow before final breakup.

Black Spruce Cutting Methods

Results

Figure 8 shows the pattern of snow accumulation and melt under each of the stand conditions studied in black spruce. During the period of accumulation the open areas--open patches and the clear-cut strips--received the most snow. Next in order was the shelterwood cutting with a fairly open canopy. This was followed by the tree selection which had smaller openings. The dense, uncut check stored the least amount.

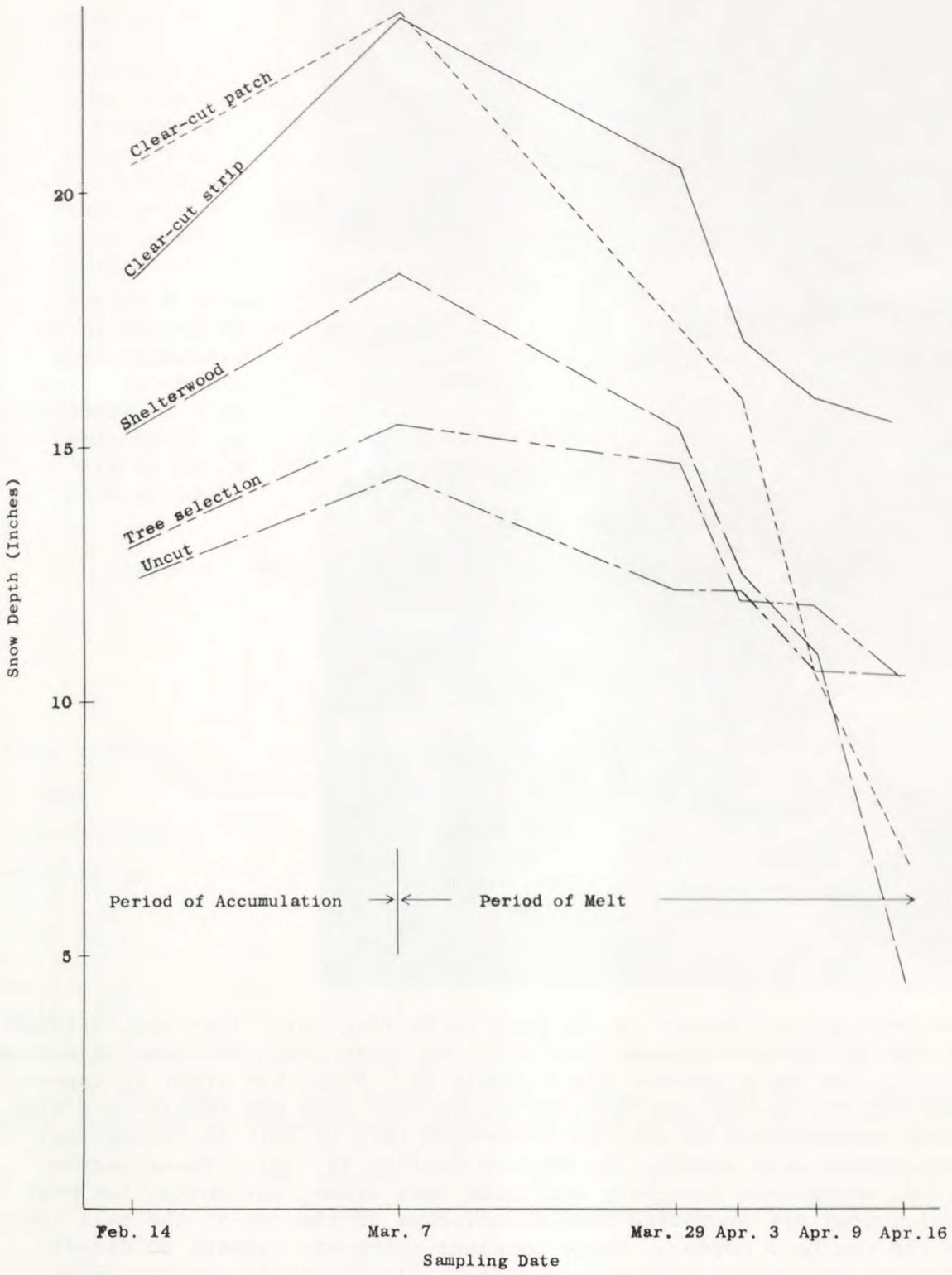

Figure 8.--Depth of snowpack under various cutting methods in black spruce.

Figure 9.--Snow is beginning to disappear from clear-cut patch. Melt is starting on north side which is exposed to sun.

The snow melted fastest in the open patch (fig. 9). This was followed by the shelterwood system (fig. 10), the check area, the tree selection system, and the clear-cut strip (table 4). From this study it appears that cutting narrow east-west strips in this type may result in a high total accumulation of snow and a reduced rate of melt in the spring. This agrees with findings in western regions (1, 15). These narrow strips accumulate snow very much like open areas, but during the melt period they are protected from direct rays of the sun by the tall trees on the southern border. Large openings which are exposed to direct sunlight lose their snow most rapidly. Silvicultural systems which open up the stand to some intermediate degree are intermediate in their ability to catch snow and prolong snowmelt in the spring.

Figure 10.--Spots of bare ground like this are exposed throughout the shelterwood cutting area as melt progresses.

Table 4.--Water content of snowpack under various cutting methods in black spruce

(Inches of water)

Date	Cutting method				
	Clear-cut strip	Single tree selection	Uncut unit	Shelterwood	Open patch
February 14	2.9	2.0	1.6	2.2	2.9
March 7	4.0	2.6	2.5	3.2	4.5
March 29	4.3	3.2	2.7	3.5	4.0
April 3	4.2	2.8	2.7	2.9	3.6
April 9	3.6	3.2	2.7	2.8	2.4
April 16 1/	3.2	2.9	2.5	1.8	1.5

1/ This was the last sampling date. Exceptionally high temperatures combined with warm rains melted all snow by April 25.

Management Implications

The results of this study show that the pattern of cutting affects the character of snow accumulation and melt.

Where clear cutting is an accepted silvicultural practice, strips or narrow openings in an east-west direction are superior to large, clear-cut blocks for accumulating snow (fig. 11). Strip cuttings also accumulate more snow and retain it longer than partial cuttings.

Fig. 11.--Deep accumulation of snow in middle of east-west strip. North side is already bare.

Discussion

Although the forest plays a complex role in snow accumulation and melt, it basically does two things. First, it acts as a barrier to snow accumulation (4, 7, 8, 9, 11). It decreases the amount of snow which reaches the ground by intercepting the falling snow. The heavier and denser the crown, the more it intercepts and less is caught on the area. The thinner the crown, the less it intercepts and more reaches the ground.

Second, after snow has reached the ground, the same factors operate but their effect is reversed. The thicker the crown, the less sunlight and wind movement and the slower the rate of snowmelt (6, 10). The thinner crown, which permitted more to reach the ground, offers less protection against sun's rays and wind movement, and snow disappears more rapidly.

Considering these factors, it is logical that the pattern of snow accumulation and melt in this study behaved as follows:

1. All open fields lost snow earlier and faster than forested areas.

2. More snow accumulated in the hardwoods, but conifers retained it longer.

3. Stand density in conifer types influenced to some degree the amount of snow accumulation and the rate of melt. Lightly stocked stands caught more snow; dense stands retained it longer.

4. The pattern of cut in conifers also affected snow accumulation and melt. East-west strips caught most snow and retained it longer than any other treatment.

5. Stocking levels in hardwoods affect snow accumulation and melt in the same way as in softwoods, but differences are smaller.

6. Mixed stands of scattered conifers and hardwoods (white pine-hardwoods) are intermediate in their reaction between pure conifers and pure hardwoods. They catch more snow than pure conifer stands and retain it longer that pure hardwood stands--both very desirable features.

7. This pattern of snow behavior conforms in general to both western areas with heavy snowfall and northeastern conditions, which have intermediate winter thaws.

These facts on snow behavior can be used to benefit both timber and watershed management in the following ways:

1. Converting open or brushy areas to forest cover will produce a timber crop and at the same time delay rate of snowmelt.

2. Converting aspen to more valuable conifer stands can help delay snowmelt while raising a higher value crop.

3. Thinning a conifer stand accelerates growth and accumulates a little more snow than leaving a dense stand unthinned. Snow melts a little more rapidly, however, as a result of thinning.

4. Where clear cutting is practiced, cutting east-west strips will tend to catch more snow and hold it longer than large block cuttings. This is desirable in terms of both water and silviculture.

5. Increasing the conifer mixture in hardwood stands by logging and stand improvement practices will improve snow behavior. Mixed stands also provide protection against entomological and pathological disasters.

The full effects of forest manipulation on water behavior cannot be determined from a study on snow alone. Many other factors need to be studied. However, these recommendations can be used to retain snow on the ground as long as possible and thus provide the opportunity for water to enter the soil rather than run off in spring freshets.

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